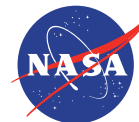


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Internal Electrostatic Discharge Tests of Micro-D Connectors for Planned Europa Mission

James Chinn, Wousik Kim, Nora Low, Eduardo Martin, Dennis Thorbourn, Marianne Smithfield

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Outline

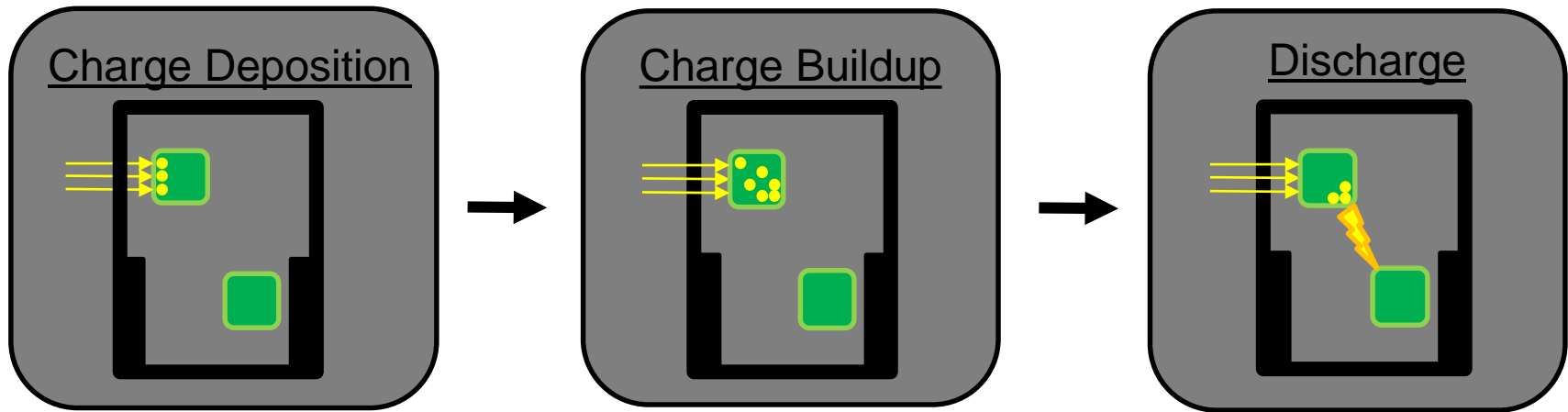
- Introduction to Planned Europa Mission
- Introduction to Internal Charging
- Overview of Test Objective and Procedure
- Sample Preparation
- Test Setup
- Test Conditions
- Results
- Conclusions

Planned Europa Mission

- Jupiter orbiter making ~45 flybys of Jupiter's moon, Europa
 - Expected launch date in 2020's
- Objective would be to investigate the habitability of the moon
- Taking measurements to characterize the atmosphere, water ice crust, suspected sub-surface ocean, and rocky interior
 - Temperature, Composition, Interactions at the boundaries between layers
- Radiation environment around Europa's orbit is very high
 - Significant threat posed by internal charging

Internal Electrostatic Discharge (IESD)

- High energy electrons penetrate spacecraft and deposit internal to electronics
- As charge accumulates, high electric fields develop, resulting in arcing
- Current arcs can damage electronics and jeopardize missions



Characterizing IESD Threat to Planned Europa Mission

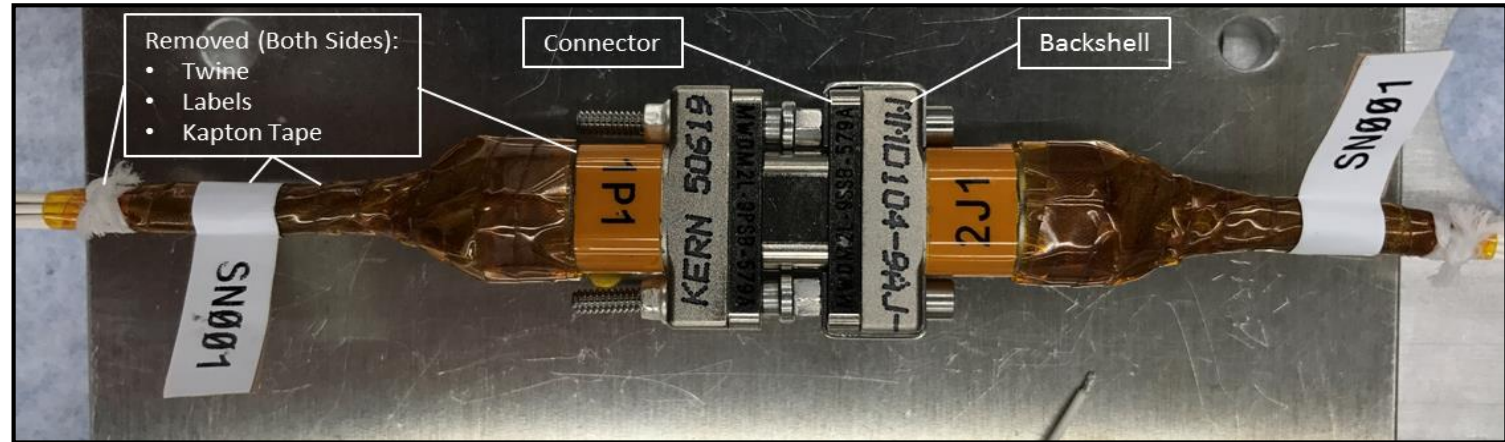
- IESD design environment [1]
 - Data from which environment was defined comes primarily from Galileo instruments
 - Defined as a 40-hour worst-case environment, experienced during flyby of Europa
 - Maximum resistivity of on-board dielectrics specified to ensure that accumulated charge bleeds off between flybys
- Many components are subject to internal charging
 - Any insulator or floating metal – this report focuses on insulators in micro-D connectors
 - A test campaign was run to assess the risk posed by micro-D connectors

Test Objective and Procedure Overview

- Test objective was to determine the Internal Electrostatic Discharge threat to spacecraft electronics from Micro-D Connectors.
 - Connectors were exposed to an electron beam calibrated to induce in them a charging profile representative of that expected in flight.
 - Voltage of discharge pulses from the connectors were recorded and a Human Body Model (HBM) class rating was assigned to each connector to characterize its IESD threat.
 - Four connectors were tested:
 - 9-Position Glenair
 - 9-Position ITT
 - 100-Position Glenair
 - 100-Position ITT
- The test results apply to these particular Glenair and ITT Micro-D Connectors, as well as other Glenair and ITT Micro-D connectors that have equivalent or thicker shielding, the same dielectric material, and equivalent or thinner dielectric thicknesses.

Sample Preparation (1)

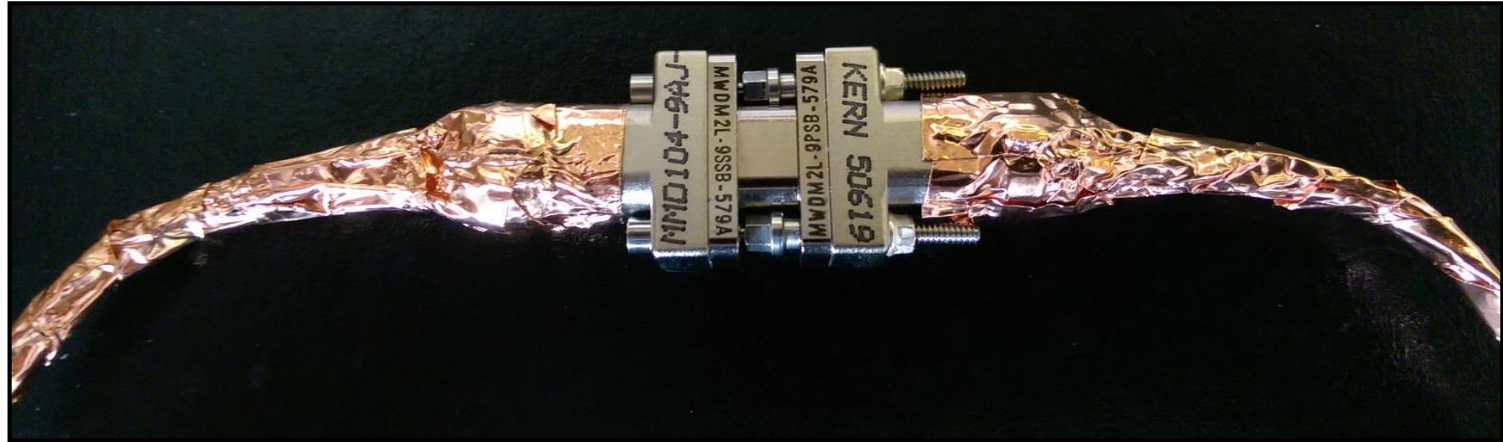
- Connectors received and prepped to flight-like condition
 - Labels, Kapton Tape, and Twine were removed



9-Position Glenair Connector Set as Received from the Cable Shop

Sample Preparation (2)

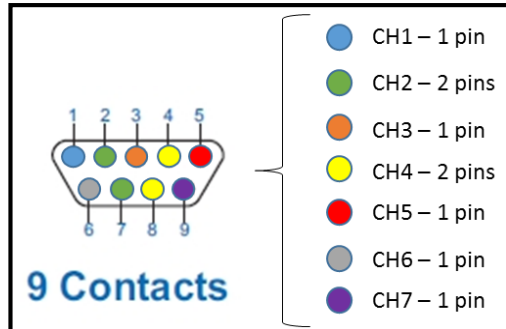
- Connectors received and prepped to flight-like condition
 - Connector set cleaned with ethanol and wrapped with conductive-adhesive Cu tape (3M 1181)
 - Cu tape served only to block low energy scattered electrons from depositing in wire insulators



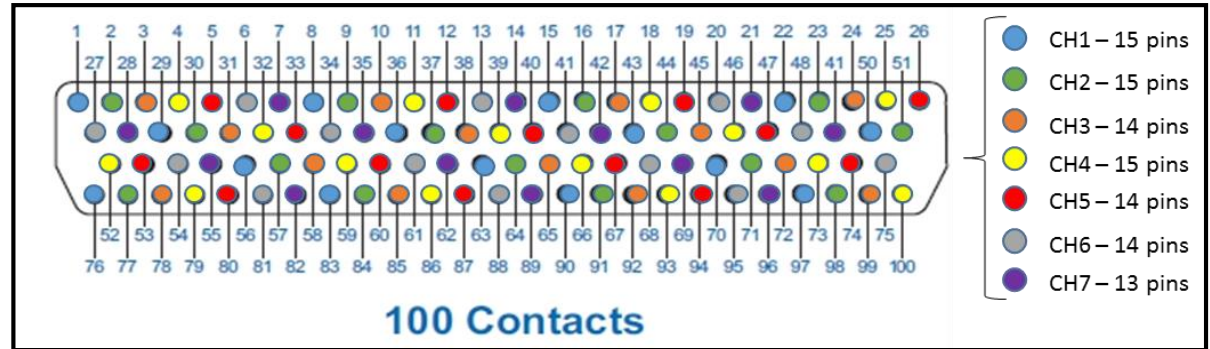
9-Position Glenair Connector Set after Removal of Twine, Labels, and Kapton Tape, and addition of Cu Tape

Monitoring Scheme (1)

- The test chamber had 7 feedthroughs available to monitor the samples.
- As such, in both the 9-Position and 100-Position connectors, pin leads were electrically connected into 7 groups.
- Grouping was such as to preserve information about amplitude of discharge. Some information about location of discharge was necessarily lost



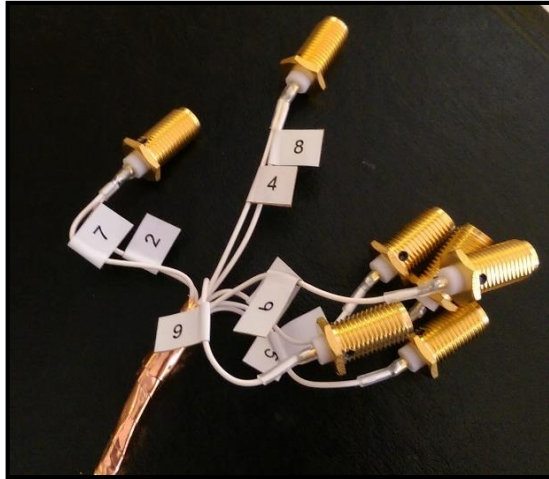
9-Position Connector Pin-to-Channel Wiring Scheme



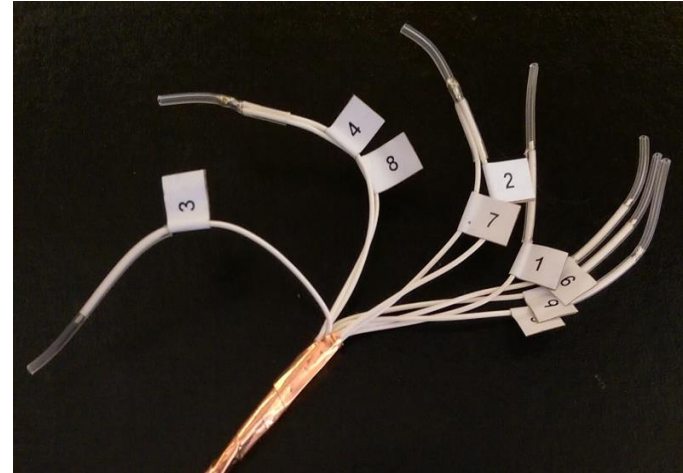
100-Position Connector Pin-to-Channel Wiring Scheme

Monitoring Scheme (2)

- The test chamber had 7 feedthroughs available to monitor the samples.
- As such, in both the 9-Position and 100-Position connectors, pin leads were electrically connected into 7 groups.



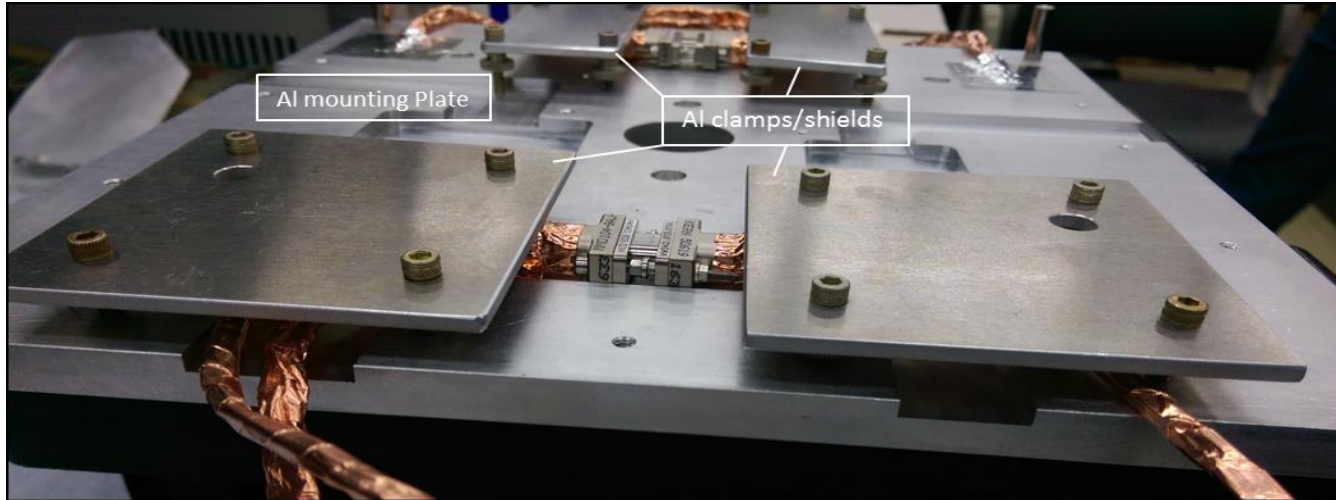
Monitored Side of 9-Position Glenair Connector Set.
Pins 7 and 2 are tied together, as are pins 8 and 4.



Insulated (Floating) Side of 9-Position Glenair Connector Set.
Again, pins 7 and 2 are tied together, as are pins 8 and 4.

Test Setup (1)

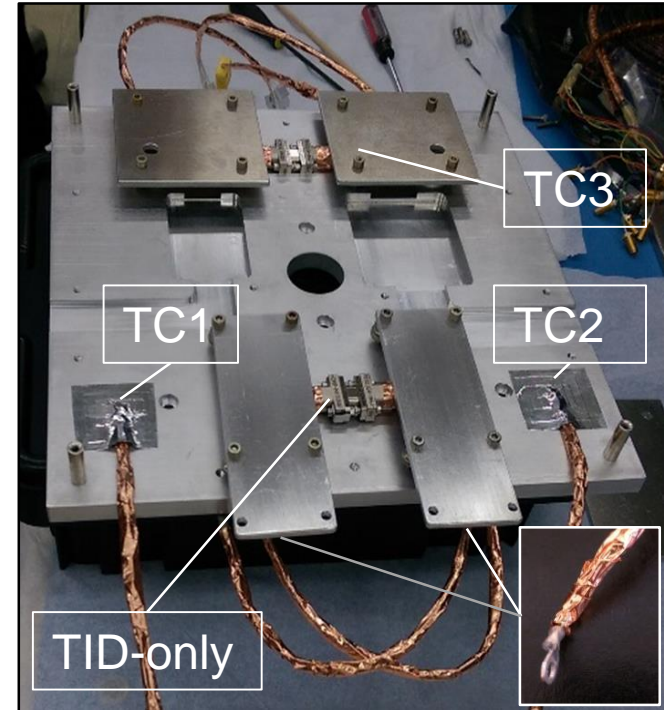
- Connectors held down with Al plates.
- The plates also serve to shield the connector wiring; the IESD response of the wiring was not desired in this test.



9-Position Glenair Connectors on Mounting Plate with Al Clamps/Shields Installed

Test Setup (2) – Thermocouple Installation and TID Test

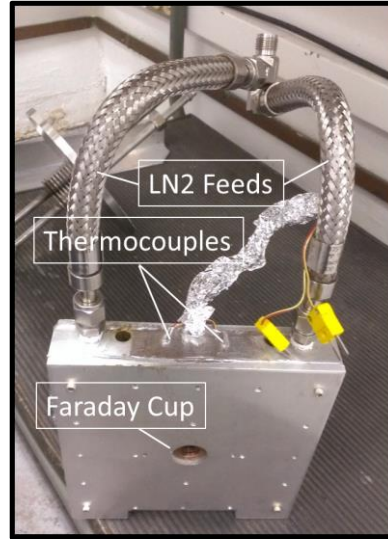
- Each test except for the 9-Position ITT test included a second connector set in the chamber only for TID testing.
- The TID connectors were prepared the same way as the ones being tested for IESD except that all pins on both ends of the connectors were electrically tied together and finished with a ground lug.
- Three thermocouples were installed. Two on the mounting plate, and one on the shielded portion of the backshell of the monitored connector.



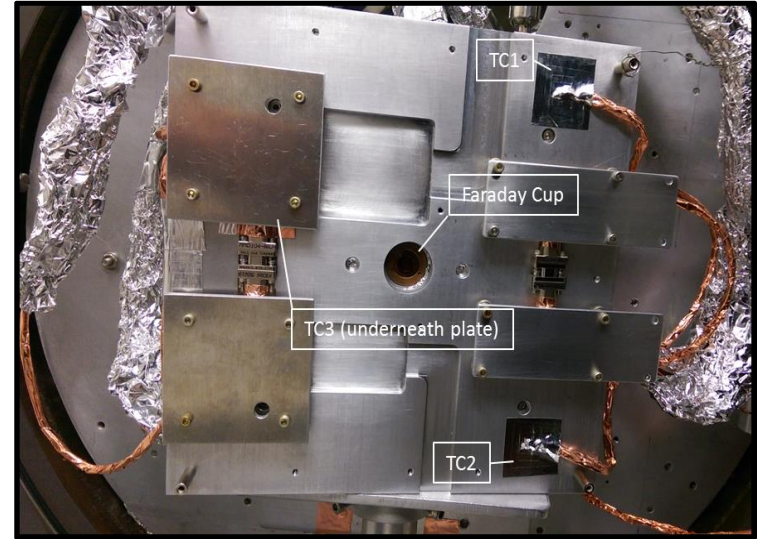
9-Position Glenair Connectors on Mounting Plate with Al Clamps/Shields Installed. TID ground lug configuration shown bottom right.

Test Setup (3) – Chamber Installation

- The populated mounting plate was assembled to the cold plate in the vacuum chamber.
- Thermocouples and connector SMAs were mated with lines in the chamber and routed to the chamber feedthrough.
- All exposed dielectrics on the connector/ thermocouple leads and chamber feedthrough lines were covered with aluminum foil to block low energy scattered electrons.



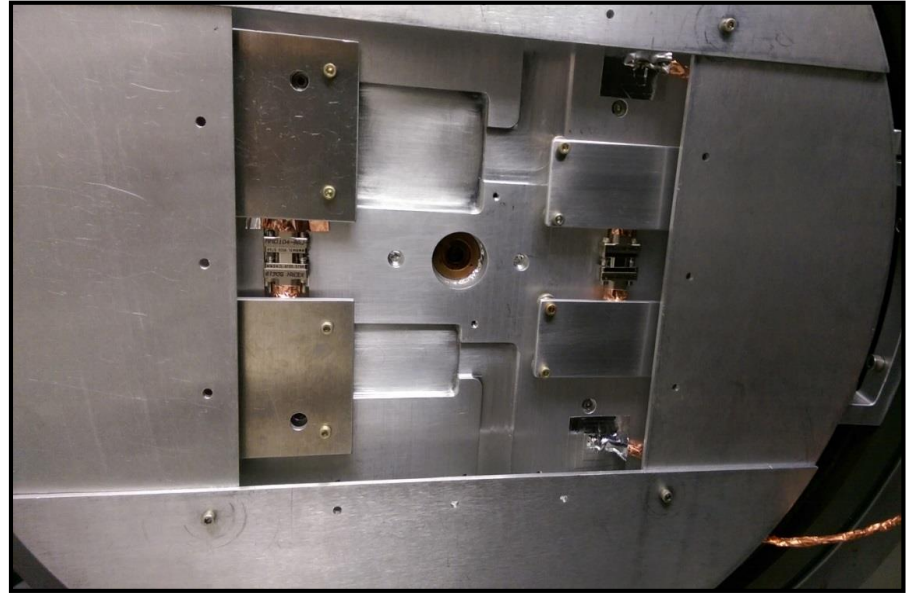
Chamber Cold Plate



9-Position Samples on Mounting Plate with Thermocouples. Assembled with Chamber before Beam Shields Installed.

Test Setup (4) – Additional Beam Shielding

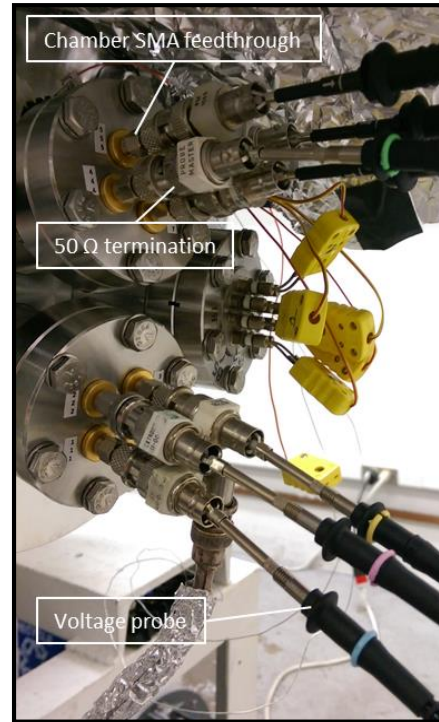
- Additional aluminum beam shields were installed to block primary electrons from depositing in thermocouple wiring, connector leads, and chamber feedthrough lines.
- The chamber was pumped down to approximately 10^{-7} Torr overnight and the cold plate was heated to 100 °C for 8 hours during the pump down to bake out the samples.



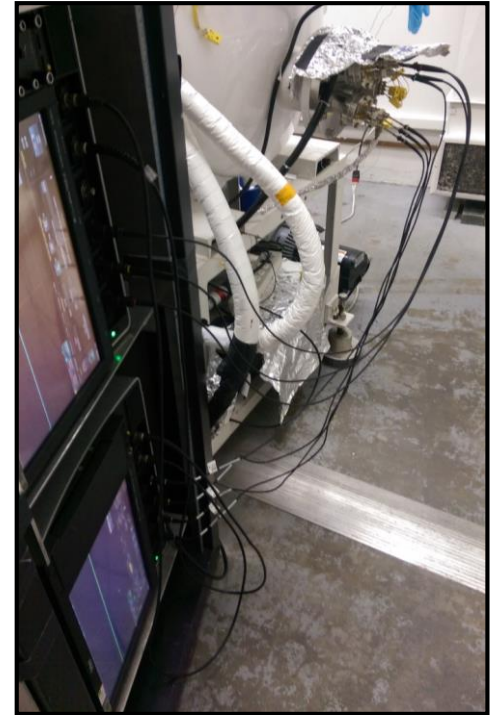
Samples Mounted in Chamber with Aluminum Beam Shields Installed

Test Setup (5) - Monitoring

- 50 Ω terminations were installed on each feedthrough that was tied to the connector.
- Voltage probes were installed to monitor the voltage drop across these termination resistors during discharge events.
- These probes were connected to two nearby oscilloscopes, which were shielded from radiation by aluminum plates.
- The oscilloscopes were monitored and controlled in a nearby room.



Exterior of Chamber
Feedthrough with Terminations
and Probes Installed



Probe and Scope Set-up

Test Setup (6) - Overview

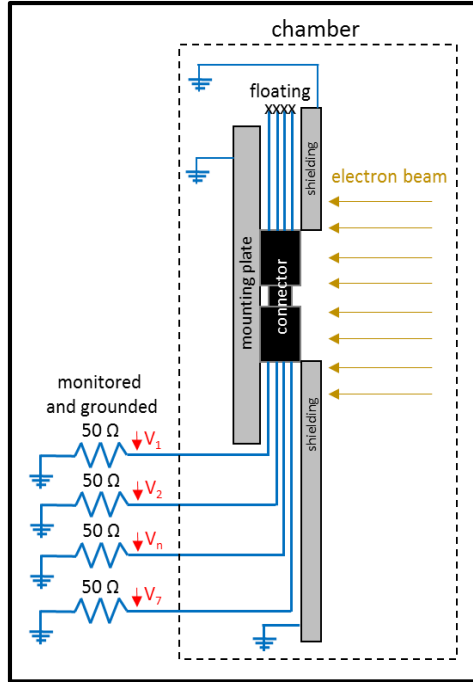
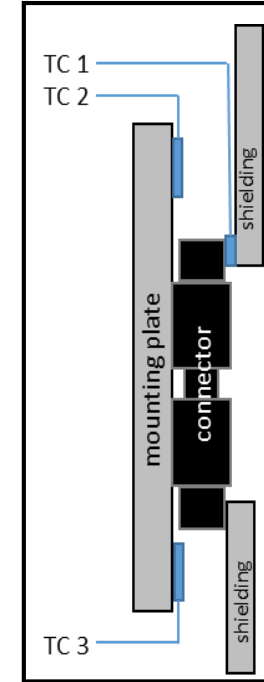


Diagram of the Test Configuration. 4 Channels Shown.
Actual Configurations had 7 Channels.



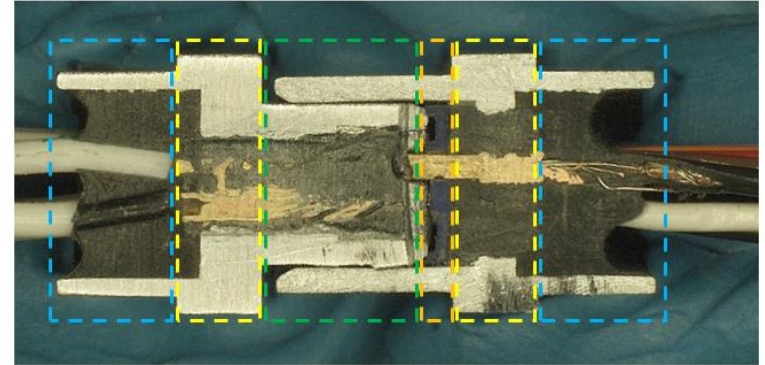
Thermocouple Monitoring
Diagram

Test Conditions (1) – Beam Energy and Flux

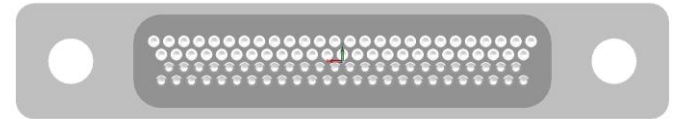
- The tests were performed at the Dynamitron facility at JPL.
- The Dynamitron produces a unidirectional, monoenergetic beam.
- The space condition is an omnidirectional spectrum of energies.
- Therefore, the Dynamitron cannot reproduce exactly the charge deposition rate expected in flight.
- A representative section of the connector geometry was identified, and the charge deposition rate expected in this area during flight was calculated using TIGER 1D radiation transport tool.
- Then a series of unidirectional, monoenergetic beams were simulated in TIGER to determine the Dynamitron beam settings that best match this charge deposition rate.

Test Conditions (2) – Shielding Geometry

- There are many regions with different housing and dielectric thicknesses.
- With a monoenergetic, 1D beam, we cannot match the space condition charge deposition rate in every region.
- We want to pick a region that will have a high charge deposition rate and be representative of a significant volume of the connector.
- The blue regions in the figure to the right have the same shielding and similar dielectric thicknesses for all connectors (including backshell).
- The green region has similar shielding as the blue region (with backshell) and consistently less thick dielectric.
- The yellow regions are somewhat unknown thickness as the vendors will not provide this to us, though based on the cross section of the 37-Position Glenair connector, it seems reasonable to believe the housing does not become extremely thin in this region.
- The orange area has relatively thin shielding for all connectors but because it is narrow, it does not represent the charging rate in the rest of the connector well, and it does not model well in 1D.
- **Therefore, the blue region was used to determine the Dynamitron beam settings.**



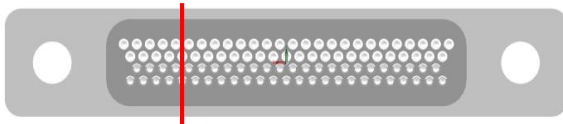
Cross Section of 37-Position Glenair Connector (No Backshell). [Courtesy of Marianne Smithfield/Nora Low]



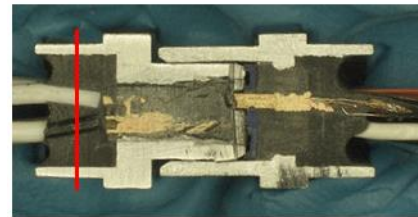
Cross Section of 100-Position Glenair Connector CAD File

Test Conditions (3) – Beam Energy and Flux

- The charge deposition rate expected during flight was calculated using TIGER 1D radiation transport tool.
- Then a series of unidirectional, monoenergetic beams were simulated in TIGER to determine the Dynamitron beam settings that best match this charge deposition rate.
- The highest charge deposition rate was determined to be the potting below the housing. The wire insulation below the potting had the second highest charging rate.
- The beam energy and flux that most closely replicate the charging rate in these two areas are 1.7 MeV and 6 pA/cm².
- The test was run at a 4x accelerated condition so the test flux was increased to 24 pA/cm².
- The 4x accelerated condition reduces the exposure time from 40 hours as specified in the IESD Design Environment, to 10 hours during testing. 10 hour tests are more practical and affordable than 40 hour tests, and previous IESD testing of Europa cabling showed the 4x condition to be similar to, and slightly conservative relative to, the 1x flight condition [2].



Cross Section of 100-Position Glenair Connector CAD File



Cross Section of 37-Position Glenair Connector (No Backshell). [Courtesy of Marianne Smithfield/Nora Low]

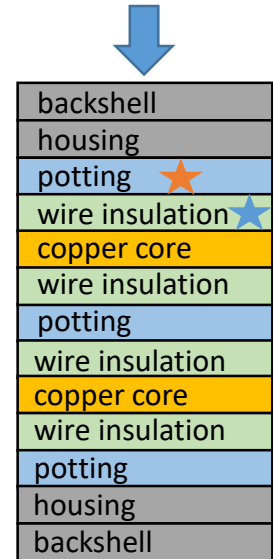


Diagram of 1D Geometry of Connector Through Red Line in other Figures (Backshell Added)

Test Results Overview

Connector Type	Test Date	Energy (Mev)	Flux (pA/cm ²)	Temperature (deg C)	Duration (hrs)	Largest Discharge Amplitude (V)	Number of Discharges	Energy (J)	Eq. HBM V [V,E] (V)		Max HBM V (V)	Factor of Safety = 2	HBM Class Rating
9 Pin Glenair	11/17/2016	1.7	24	-51	10	1.5	1	2.14E-10	45	12	45	90	1A
9 Pin ITT	11/22/2016	1.7	24	-51	10	-	0	-	-	-	-	-	1A
100 Pin Glenair	12/07/2016	1.7	24	-50	10	-	0	-	-	-	-	-	1A
100 Pin ITT	12/14/2016	1.7	24	-52	10	1	2	3.39E-10	30	14	30	60	1A

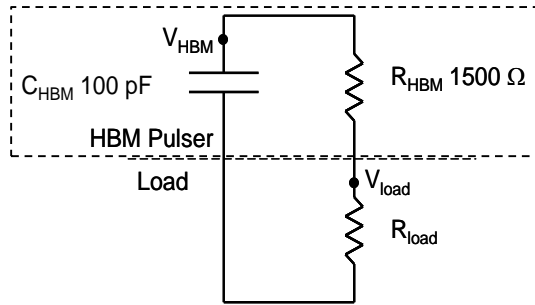
- Tests were performed at a 4x flux condition relative to the Europa IESD design environment.
- Voltages were measured across 50 Ω termination resistors.
- Only discharges with Amplitude > 250 mV were recorded.
- Column 5 “Energy (J)” lists the energy released into the termination resistor by the largest discharge. This is calculated by integrating the power dissipated in the termination resistor over the duration of the discharge.
- Columns 6 and 7 are the equivalent HBM voltage of the discharge calculated first, to correspond to the voltage dropped across the termination resistor, and second, to correspond to the energy dissipated in the termination resistor.

All four connectors tested are determined to safely interface with HBM Class 1A rated electronics.

*It was discovered after completion of the tests that an unintended factor of 2 was included in the flux calculations, making the subject tests conservative. The flux and fluence were twice their intended values.

Human Body Model (1)

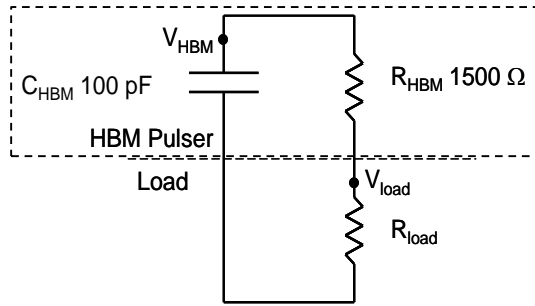
- The discharges can be characterized according to Human Body Model (HBM MIL-STD-883G Method 3015.7 [3]).



- Parts are often rated according to the maximum V_{HBM} they can withstand from the HBM Pulser circuit. (they are connected to the circuit as shown to the left as an impedance R_{load})
- During IESD testing, the HBM Pulser circuit is replaced by a discharge pulse within the test article, and R_{load} is a 50 Ω resistor.
- We measure V_{load} and back out an equivalent V_{HBM} from the HBM Pulser circuit that would have induced the same magnitude voltage across the load or energy released in the load

Human Body Model (2)

- The equivalent V_{HBM} is calculated using two methods, and the largest calculated voltage is used to classify the part. The two methods are an equivalent voltage method and an equivalent energy method.



Equivalent Voltage Method

$$V_{50\Omega} = \frac{50}{1550} V_{HBM}$$

$$V_{HBM} = 31 V_{50\Omega}$$

Equivalent Energy Method

$$E_{50\Omega} \equiv \int \frac{V_{50\Omega}^2}{R_{50\Omega}} dt$$

$$E_{50\Omega} = \left(\frac{50}{1550} \right) E_C$$

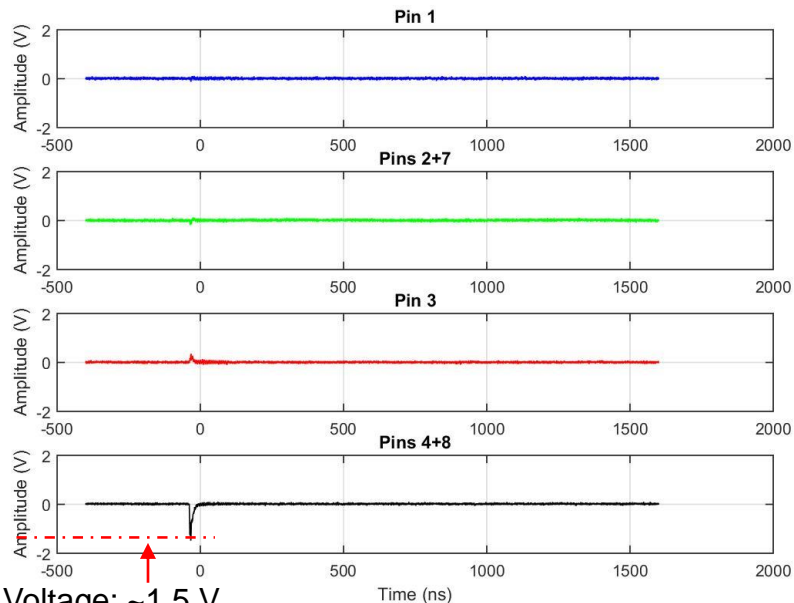
$$E_C = 31 E_{50\Omega}$$

$$V_{HBM} = \sqrt{\frac{2 E_C}{C_{HBM}}}$$

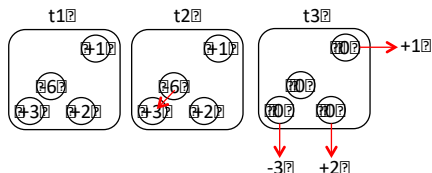
Class	HBM Voltage Range (V)
0	< 250
1A	250 - 500
1B	500 - 1000
1C	1000 - 2000
2	2000 - 4000
3A	4000 - 8000
3B	> 8000

Example Discharge – 9-Position Glenair

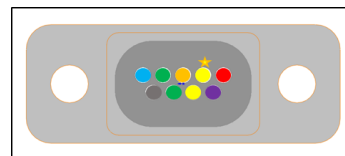
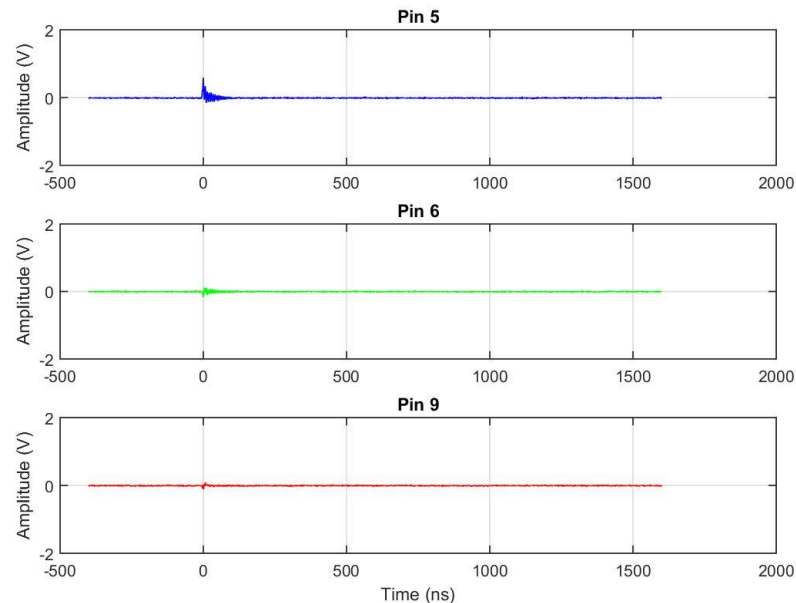
Europa_Micro-D_Connector_9Pin_Glenair_Scope1_00000



Peak Voltage: ~1.5 V



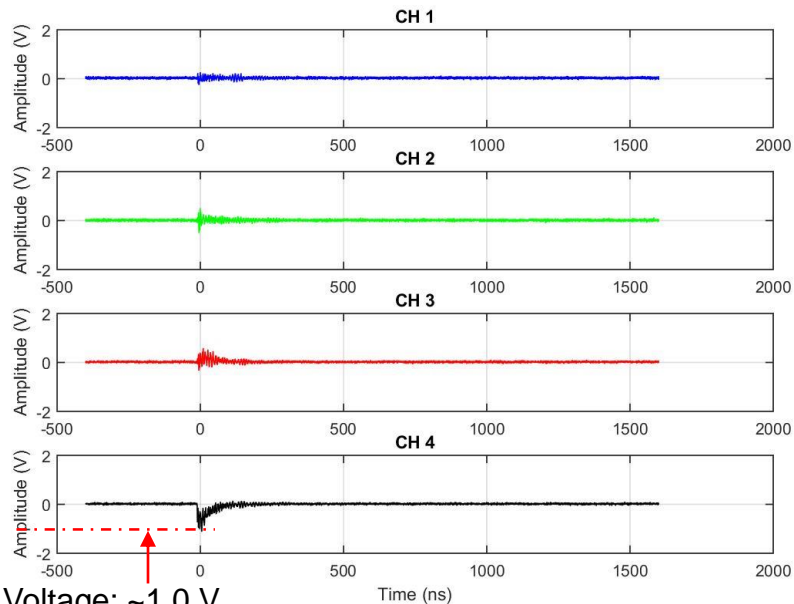
Europa_Micro-D_Connector_9Pin_Glenair_Scope2_00000



Expected Location of Discharge

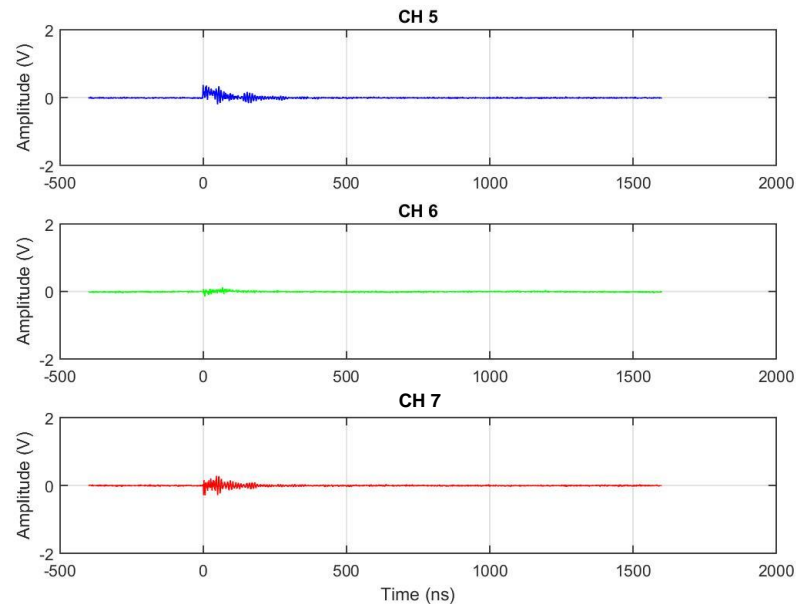
Example Discharge – 100-Position ITT

Europa_Micro-D_Connector_100Pin_ITT_Scope1_001



Peak Voltage: ~1.0 V

Europa_Micro-D_Connector_100Pin_ITT_Scope2_001



Conclusion

- The test objective was to determine the Internal ElectroStatic Discharge (IESD) threat to Europa electronics from Micro-D Connectors.
- The connectors were exposed to an electron beam calibrated to induce in them a charging profile representative of that expected in flight.
- The voltage of discharge pulses from the connectors were recorded and a Human Body Model class rating was assigned to each connector to characterize its IESD threat to Europa electronics.
- Four connectors were tested:
 - 9-Position Glenair
 - 9-Position ITT
 - 100-Position Glenair
 - 100-Position ITT

All four connectors tested are determined to safely interface with HBM Class 1A rated electronics. The test results apply to these particular Glenair and ITT Micro-D Connectors, as well as other Glenair and ITT Micro-D connectors that have equivalent or thicker shielding, the same dielectric material, and equivalent or thinner dielectric thicknesses.

References

- [1] W. Kim, J. Chinn, I. Jun, H. Garrett, Internal Electrostatic Discharge (iESD) Design Environments for Jovian Missions, in press, 2017
- [2] J. Chinn, W. Kim, E. Martin, D. Thorbourn, Europa IESD Cable Report, unpublished, 2017
- [3] United States Department of Defense, MIL-STD-883G Method 3015.7, 2006



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